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by
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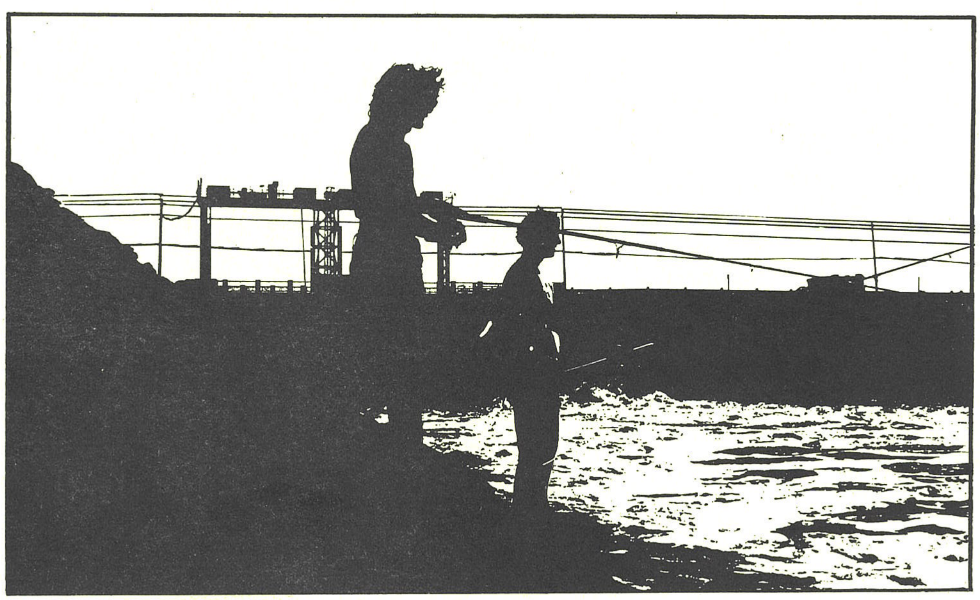

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CREEL SURVEY AND BIOLOGICAL STUDY OF THE STRIPED BASS FISHERY OF THE ANNAPOLIS RIVER, 1975

B.M. JESSOP AND W.G. DOUBLEDAY[1]

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ABSTRACT

Angling for striped bass *(Morone saxatilis)* has become an increasingly important recreation in the lower Annapolis River valley of Nova Scotia. The significance of this sport fishery was assessed by a creel survey of major fishing sites for systematic variations in fishing catch and effort during the period May 13-September 11, 1975. Parameters such as angler origin, bait used, and shore vs. boat fishing were also examined.

Three methods were used to obtain estimates of total catch and effort and their variances: (1) Horvitz-Thompson estimates, which utilized the allocation probabilities of the sampling scheme; (2) stratification "A", which stratified the data by month, location, weekdays, and weekends and holidays combined; and (3) stratification "B", which stratified the data according to time of day, month and location. The Horvitz-Thompson and stratification "B" methods, perhaps the most reliable, estimated total catch and effort at 872 fish and 12,663 hours and 813 fish and 12,675 hours, respectively. The relative efficiency for estimating total catch and effort, compared with the efficiency of simple random sampling, was calculated for each sampling design.

The age-structure, length and weight composition, growth rate, and sex ratio were determined for the stock of angled fish. Comparison of these parameters with data from a 1972 study revealed several differences.

Concentrations of PCBs and DDT in striped bass ovaries averaged 3.66 ppm and 1.75 ppm, respectively, while mercury levels in muscle tissue averaged 0.20 ppm.

RESUME

La pêche sportive au bar rayé *(Morone saxatilis)* est devenue une activité récréative de plus en plus importante dans la vallée inférieure de la rivière Annapolis en Nouvelle-Écosse. On a évalué l'importance de cette pêche sportive en procédant à une enquête sur les prises dans les principaux lieux de pêche en vue de déterminer les variations systématiques dans les prises de poissons et l'activité de pêche au cours de la période du 13 mai au 11 septembre 1975. On a également étudié des paramètres tels le lieu de provenance du pêcheur, l'appât utilisé et la pêche de plage par opposition à la pêche en bateau.

On a employé trois méthodes pour obtenir des estimés des prises et de l'activité globales ainsi que de leurs variations: (1) les estimés Horvitz-Thompson, qui utilisent les probabilités de répartition du programme d'échantillonnage; (2) stratification "A", qui stratifie les données par mois, endroits, jours de la semaine, et fins de semaine et jours fériés combinés; et (3) stratification "B", qui stratifie les données selon l'heure de la journée, le mois et l'endroit. La méthode Horvitz-Thompson et la méthode de stratification "B", soit peut-être les deux plus dignes de foi, ont évalué les prises et l'activité globales à 872 poissons et 12,663 heures, et 813 poissons et 12,675 heures, respectivement. On a calculé, pour chaque méthode d'échantillonnage, l'efficacité relative de l'estimé des prises et de l'activité globales par comparison à l'efficacité du simple prélèvement d'échantillons au hasard.

On a déterminé la structure par âge, la composition par longueur et par poids, le taux de croissance et les rapport des sexes pour la quantité de poissons pêchés. La comparaison de ces paramètres à des données tirées d'une étude effectuée en 1972 a révélé plusieurs différences.

Les concentrations en PCB et en DDT dans les ovaires du bar rayé atteignaient respectivement en moyenne 3.66 ppm et 1.75 ppm, alors que les niveaux de mercure dans le tissu musculaire atteignaient en moyenne 0.20 ppm.

INTRODUCTION

Angling for striped bass (*Morone saxatilis*) has become an increasingly important recreation in the lower Annapolis River valley. Estimated catches of striped bass increased from about 1,600 fish in 1960 to over 58,000 in 1970 and declined to over 26,500 in 1975 (Conservation and Protection Branch monthly reports). Such bountiful catches could only come from a major sport fishery. By comparison, Otto (1971) estimated that 23,500 and 6,500±4,200 striped bass were caught in 1969 and 1970, respectively, in the extensive sport fishery along the central Maine coast.

Management of fishery resources is based principally on knowledge of fishing catch and effort, fishing methods, location of capture and biological information on the stock. For a sport fishery, this information is commonly obtained via a creel census or survey. A creel census involves complete enumeration of the catch and effort expended by the entire population of anglers participating in the fishery (Carlander et al. 1958; Robson 1960), while a creel survey collects data from a sample(s) of the angler population (Cochran 1963; Otto 1971). Penney (1973) investigated aspects of the life history of striped bass in the Annapolis River and gathered information on angler catch and effort. Consequently, a bag limit of five fish per day was introduced in 1975 on this previously unregulated fishery. More detailed information was deemed necessary to better evaluate the status of the striped bass population prior to possible establishment of additional regulations.

The information required included a description of the angling fishery, estimate of catch and effort, measurement of economic importance, assessment of regulations, and life history data. Simultaneous maximization of information in all subject areas is difficult to achieve in a single study and was not attempted here.

The major objective of this study was the conduct of a creel survey to estimate the total catch and effort on the striped bass fishery of the lower Annapolis River between May 13 and September 11, 1975. This objective was achieved by sampling all major fishing areas for systematic variations in fishing catch and effort with time. A stratified sampling design increased precision and efficiency of the estimates.

DESCRIPTION OF STUDY AREA

The Annapolis River flows southwest and empties into the Annapolis Basin in southwestern Nova Scotia (Fig. 1). The basin joins the Bay of Fundy through Digby Gut. The main stem of the river has a meander length of approximately 142 km and drains an area of 2,130 km^2. Width of the Annapolis Valley varies from 4.0 km at Digby to 8.9 km in the valley's upper reaches, and elevation of the valley floor rises from sea level to 30-50 m over the same distance.

FIG. 1. Map of Annapolis River system.

In 1960, the Maritime Marshland Rehabilitation Administration of the Nova Scotia Department of Agriculture, in cooperation with the Nova Scotia Department of Highways, completed construction of a causeway across the Annapolis River at Annapolis Royal. The causeway serves both as a highway bridge and as a water-level control structure for reclamation of marshland for agricultural purposes. Two gates, each 8.8 m wide by 10 m deep, and a free-flow gap of 4.6 m provide water-level control. The free-flow gap permits free passage of fish in either direction (Smith and Coates 1960).

The river above the causeway is an extensive, highly stratified estuary, with a wedge of saline water overlain by outflowing low-salinity water (Jessop 1976). Stratification is probably stable because of reduced tidal fluctuation resulting from construction of the causeway, and the presence of a deep channel and wind-sheltered middle reach of estuary (Green 1968). Saline water extends about 2 km above Bridgetown during the summer low-flow period, and head of tide is located near Paradise, about 39 river km above Annapolis Royal.

Much of the Annapolis Valley is under cultivation – mainly mixed farming, with some specialized farming such as fruit orchards and poultry farms. Most soils on the bordering mountains and many in the valley are formed from tills composed largely of material from nearby bedrock (Smitheringale 1973). Valley till soils contain high amounts of clay and silt derived from shale and sandstone, while other soils derive from easily weathered glacial outwash deposits.

Chemical analyses of Annapolis River water were made by the Nova Scotia Department of the Environment at 10 sites between the causeway and Aylesford, on nine dates from June through August, 1974. Dissolved oxygen levels were generally highest near the causeway, declining with distance upstream. For example, on June 9, dissolved oxygen was 10.1 mg/l at the causeway and 8.0 mg/l at Aylesford, while on August 13, there were 9.2 and 7.5 mg/l, respectively. Oxygen saturation averaged 95.9% (range 80.6%-127.3%) for all sites combined, while pH averaged 7.46 (range 6.9-8.6). Generally, pH values were highest at the causeway, declined with progression upstream to Wilmot, then sharply increased to form a plateau at the remaining sites.

Upriver, the water is a strong brown color, due mainly to dissolved organic materials and suspended solids, which disappear only well down the estuary. Alkalinity ranged from 4 to 7 mg/l except at the causeway, where it was never less than 70 mg/l. Phosphate concentrations rarely exceeded 50 mg/l except at Wilmot, where concentrations were seldom less than 50 mg/l. The nitrogen-phosphorous ratio was a reasonable 32:1. Above Paradise, observations of algal mats on the stream bottom suggest a degree of pollution.

METHODS

The creel survey design used in this study is based on a program of stratified random sampling. The following analysis of the statistics of creel survey design is modified from Otto (1971).

Since fishing pressure in a region can be considered to be stratified through space and time (Robson 1960), a sample population (P) must fully encompass the fishery and account for variability within the population. Such a population is constructed by partitioning the total area of the fishery and the fishing season into appropriate short intervals. The population (P) of possible samples then consists of a finite number (N) of ordered pairs, each consisting of one location (a) and one time interval (t), where N = at. This can be visualized as a rectangular grid which plots location versus time interval. Observation of all location segments during all time intervals results in enumeration of all fishermen present, all hours of effort, and all fish caught.

If a fishery is homogeneous, a simple random sample drawn from the population of area-time pairs provides a good estimate of average fishing pressure and catch per unit effort. Fishing pressure usually varies systematically through the season, often being much heavier on weekends and holidays than on weekdays (Robson 1960). Changes in fishing pressure might also occur with time of day or week in season (Carlander et al. 1958), as well as with relative proximity to urban centers, campgrounds, roads, etc. Increased heterogeneity within the fishery requires an increased number of samples to obtain precise estimates of population totals, and reduces the efficiency of a simple random-sampling design.

Stratification allows comparison of subpopulations within a population and may result in more precise estimates of population parameters (Cochran 1963). Precision of sample estimates depends upon the degree in which construction of strata reflects variability of characteristics being measured (Hansen et al. 1953, cited by Otto 1971) and the allocation of sample size within each stratum. If sampling fractions are small, the variance of a simple random sample is greater than the variance of a proportionally allocated stratified random sample, which in turn is greater than variance of an optimally allocated stratified random sample. In proportional allocation, the sampling fraction remains constant from stratum to stratum while in optimal allocation, the sampling fraction (n_h/N_h) is proportional to the standard deviation within each stratum.

Sampling Design and Analysis

Variability in fishing pressure may be related to fluctuations in some factor or set of factors governing the behaviour of fish and fishermen. Subdivision of a population of area-time pairs into strata need not be done quantitatively or even objectively. Division of the sampled population depends only upon the construction of homogeneous, unique subpopulations and upon the allocation of sample size.

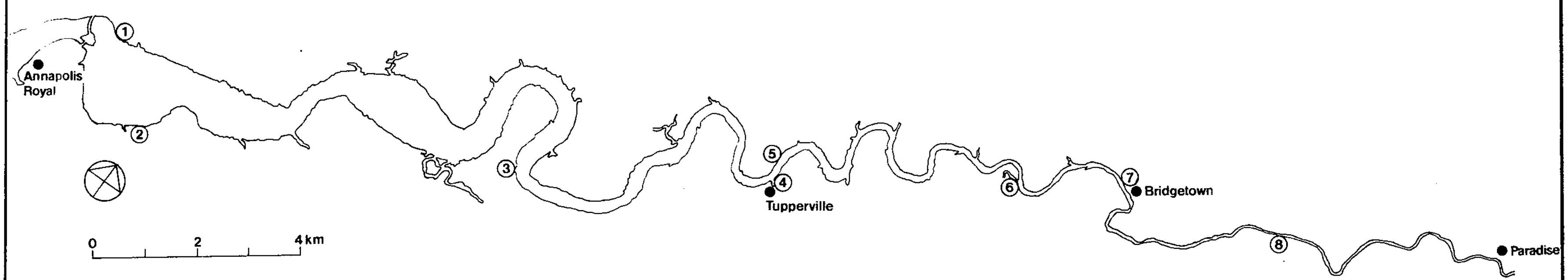
Identification and classification of areas where striped bass fishing occurred was based upon information obtained from local fishery officers, Mr. G.H. Penney (Fisheries and Marine Service, Halifax), and personal observation of the fishing areas. Access areas were classified according to geographic location, on the basis of "upriver", "causeway" and "other" locations. There were eight upriver locations: trailer park, boat club, Round Hill, Tupper Brook, midway, Bloody Creek, Bridgetown and Paradise (Daniels Brook), in ascending order from the river mouth (Fig. 2). The boat club site was eliminated in June and the Bloody Creek site in July, because of negligible fishing activity. During May, the causeway area was sub-divided into upriver and downriver locations; from June onward, it was considered as one site. Other locations consisted of the Bear and Allain rivers. Bear River was sampled during May and June, the Allain River during July through September.

Each day was divided into six 4-hr periods, i.e., 0100-0500 hours, 0500-0900 hours, etc. The 0100-0500 hour time period was not sampled. Upriver fishing activity occurs almost exclusively during daylight hours. At the causeway, night fishing is common but less intensive than daytime fishing. All days of the month were sampled – weekdays twice per day, and weekends and holidays four times per day, since weekend and holiday fishing pressure was expected to be heavier than that of weekdays. Holidays and weekend days were assumed to experience comparable fishing pressure.

The frequency of sampling at a given site (Table 1) was weighted on the basis of the expected fishing intensity at the site, as determined from observations during the previous month and from information on historic trends in the fishery. Weightings in May, the first sampling month, were based upon information about the fishery from the local fishery officers. Prior to mid-to-late June, fishing pressure tends to be concentrated at the upriver sites; thereafter, it is concentrated at the causeway.

Randomization of area-time pairs was achieved by coding separately each time interval and location, then matching the codes with numbers drawn from tables of random permutations of 9 and 16 numbers, respectively (Cochran and Cox 1957). The randomized lists of time and location were then paired by date and a sampling schedule was prepared.

Date, time of day, location, weather, number of anglers, residency, time fishing, catch and baits used were recorded for each 4-hr sample period. At the beginning of each sample period, all striped bass fishermen present at the access area were interviewed to determine when they began fishing, their catch, residency and bait used. The observed start of fishing



No.	Location
1	Trailer Park
2	Boat Club
3	Round Hill
4	Tupper Brook
5	Midway
6	Bloody Creek
7	Bridgetown
8	Paradise (Daniels Brook)

FIG. 2. Map of creel survey area and sampling sites.

was recorded for newly arrived fishermen, as was the time of cessation of angling by each fisherman. Break periods of more than about 10 minutes were deleted from the observed fishing time.

TABLE 1. Weightings for sampling frequency by site and month.

Location	Monthly weightings				
	May	June	July	August	September
Causeway	4	3	4	7	7
Trailer park	2	2	1	1	1
Boat club	1	-	-	-	-
Round Hill	2	1	1	1	1
Tupper Brook	2	2	2	1	1
Midway	2	2	2	2	2
Bloody Creek	2	1	-	-	-
Bridgetown	2	1	1	1	1
Paradise	2	2	2	2	2
Bear River	2	1	-	-	-
Allain River	-	-	1	1	1
Totals	21	15	14	16	16

Reported fishing effort refers to the time interval from the reported start of fishing to the observed cessation of fishing or the end of the sample period, and can exceed the duration of a sample period (4 hr). *Observed fishing effort* is the time that the angler was observed fishing during a sample period and cannot exceed four hours. All catches are considered reported catches, since the time of fish capture was not recorded. *Completed fishing trips* are trips finished during the sample period, while *incomplete trips* are those in which the angler continues fishing past the end of the sample period.

For reasons explained later, catches from complete trips and observed effort for all trips were analyzed in detail. Each sampling unit (area-time pair) on a given day was assigned the sum of the hours fished by complete and incomplete trips during that period. The first sampling unit of the day was extended from 0500-0900 hours to 0100-0900 hours to account for overnight trips.

Biological Sampling

Scale samples were collected and length (to nearest 0.5 cm), weight (to nearest 20 g), state of maturity, sex, date and location of capture were recorded for most fish observed. Very few fishermen refused permission to sample their catch. Since it was impossible to collect complete information for every fish, the numbers of fish may vary in each data category. Some fish caught outside of sampling periods were also sampled.

Scales were independently read twice, and where differences occurred in age assessment, a third time. Majority agreement was accepted as the correct age and all readable samples were assigned an age. A virtual annulus was counted at the scale edge unless recent growth was evident.

Ovaries were collected from 18 angled fish, wrapped in aluminum foil and quick-frozen for analysis of PCBs (polychlorinated biphenyls) and DDT and its metabolities by the Fish Inspection Laboratory, Halifax.

Samples of caudal musculature from seven angled fish were analyzed for mercury content by the Environmental Protection Service, Bedford Laboratory.

RESULTS

Sampling Statistics

A total of 291 4-hr periods was sampled between May 13 and September 11: 169 at upriver sites, 99 at the causeway and 23 at other sites. One hundred and thirty-one samples contained shore-based anglers, of which four samples containing 10 anglers were at the "other" sites (Bear and Allain rivers). In the following analysis only upriver and causeway sites will be considered. The low sampling frequency at Bear and Allain rivers did not justify detailed analysis. The apparently low catch and effort at these sites, perhaps partially the result of low sampling effort, was confirmed by additional observation and information from anglers, although the Allain River was occasionally active in August. No correction has been made for the variable sampling rates at each site, so that the analysis is representative only of the samples, not the sampled population. The error introduced would be greatest where the sample size is smallest, but is unlikely to alter general trends or conclusions. Data on anglers fishing from boats are located in Appendix A.

Interviews were conducted with 1,192 anglers encountered in 127 sample periods at the causeway and upriver sites, for an average of 9.4 interviews per sample (range 0-31). Total reported fishing effort was 2,496.8 hours, during which 131 striped bass averaging 4 kg in weight were caught. The catch rate was 0.05 fish per hour or, conversely, 19.1 hours on average were expended for each fish caught. On a per sample basis, reported catch rate ranged from 0 to 2 fish per sample hour. Total catch was made by 88 fishermen or 7.4% of those interviewed.

Almost 76% of the shore-based striped bass anglers sampled were from Nova Scotia (Table 2). Over 55% of Nova Scotian anglers were from Annapolis and Kings counties. The United

States and other countries accounted for about 17% of anglers interviewed, while almost 8% came from other provinces.

TABLE 2. Residence of striped bass anglers in relation to fishing location, as a percentage of total anglers interviewed (N=1,192), Annapolis River creel survey, 1975.

Residence	Location		
	Causeway	Upriver	Totals[1]
Total Nova Scotia	65.4	10.1	75.5
Annapolis County	20.1	6.2	26.3
Kings County	12.6	2.9	15.4
Halifax County	13.2	0.8	13.9
Other counties	19.6	0.3	19.9
Other provinces	7.6	0.3	7.9
United States and other countries	16.5	0.1	16.6
Totals	89.6	10.4	100.0

[1]Totals may differ due to rounding errors.

From April through mid- to late June, most striped bass fishing occurred upriver; while from late June on, it was concentrated at the causeway. Approximately 11% of total sampled angler effort and 24% of reported catch originated at upriver sites; the remainder occurred at the causeway (Table 3). Anglers fishing upriver were almost entirely (97%) Nova Scotia residents, of which 90% were from Annapolis and Kings counties. About 73% of the fishermen at the causeway were Nova Scotians; the remainder were tourists from other provinces (9%) or other countries (18%).

Virtually all fish caught upriver were taken by anglers from Annapolis and Kings counties (Table 3). Annapolis County residents reported fishing slightly less total time than did Kings County residents, but both had comparable catch rates (catch per angler and catch per hour). At the causeway, anglers from Kings County had the highest catch rate, followed closely by foreign (mainly American) anglers. Residents of other provinces reported a mean fishing effort similar to that of provincial and foreign residents but none caught any striped bass. Local fishermen caught 53% of the total fish angled by provincial residents at the causeway, and spent one-third less effort than other provincial residents in doing so.

Baits used by striped bass anglers were placed in five

TABLE 3. Striped bass catch, effort and catch/effort statistics, according to angler residency and fishing location, Annapolis River creel survey, 1975.

Location	Residence	No. of anglers	Reported effort (hrs)	Reported catch	Av. fish per angler	Av. hours per angler	Av. fish per hour
Causeway	Annapolis County	239	365.7	17	0.07	1.53	0.05
	Kings County	150	289.3	22	0.15	1.93	0.08
	Halifax County	157	338.3	13	0.08	2.15	0.04
	Other Nova Scotia counties	234	655.7	21	0.09	2.80	0.03
	Other provinces	91	167.4	0	0.00	1.84	0.00
	United States and other countries	197	411.4	27	0.14	2.09	0.07
	Totals	1,068	2,227.8	100	0.09	2.09	0.04
Upriver	Annapolis County	74	161.1	20	0.27	2.18	0.12
	Kings County	34	85.4	10	0.29	2.51	0.12
	Halifax County	9	8.3	0	0.00	0.92	0.00
	Other Nova Scotia counties	3	7.3	0	0.00	2.42	0.00
	Other provinces	3	4.5	1	0.33	1.50	0.22
	United States and other countries	1	1.5	0	0.00	1.50	0.00
	Totals	124	268.0	31	0.25	2.16	0.12
Totals		1,192	2,495.8	131	0.11	2.09	0.05

categories: whole alewife, live or dead; cut pieces of alewife or herring; plugs, including rapala, cisco kid and various poppers; bucktail (lead-headed, single hook with hair skirt); and "other" lures and bait, including spoons, spinners, squid, clams, eels and eel lures, etc.

Some anglers, of course, tried a variety of baits during a fishing trip and the bait type most often used was recorded. Most anglers, particularly those using alewife or bucktails, continued with that particular bait. At upriver sites, anglers using live alewvies spent a considerable part of their fishing effort jigging for alewives to use as bait. The popularity of baits varied with fishing location, such that 52% of anglers interviewed used whole alewives when fishing upstream and 71% of anglers used bucktails when fishing the causeway (Table 4). At each location, the most successful baits were also the most popular. Catch per angler was three times greater for those using whole alewives at upriver sites than for those using bucktails at the causeway, while mean fishing effort per fish caught was less.

Seasonal Variation in Fishing Effort and Catch

Fishing activity both at upriver sites and at the causeway began during mid-May (Fig. 3 and Appendix B). At the upriver sites, fishing pressure increased until the end of May, then began a gradual decline toward cessation in mid-July. Catch per hour (sum of all fish reported caught divided by all fishing hours) peaked during early June. There was no consistent relationship between fishing effort and catch. The intensity of fishing activity and catch per angler at the upriver sites as portrayed is somewhat misleading in that the data are averaged over eight sites in May, seven in June and six in July, while fishing activity and catch were actually concentrated at only two sites (Paradise and Tupper Brook). Consideration of just these two sites would increase these two statistics by more than three times.

At the causeway, fishing pressure increased sharply between late May and late June, oscillated markedly at a high level until late July, declined sharply through late August, then increased sharply during the first week of September (Labor Day holiday). Catch per hour was highest, and relatively constant, during late May and early June, declined in late June, stabilized at a moderate level between early July and mid-August, then declined to zero for a three-week period before increasing again in early September.

Comparison of the mean number of anglers per sample fishing at the causeway on weekends and holidays combined, versus weekdays, suggests that more anglers fished on weekdays than on weekends (Table 5). Weekdays in August experienced a surge of non-local anglers, which set the overall trend, while local anglers were about as numerous on weekends as on weekdays.

TABLE 4. Striped bass catch, effort and catch/effort statistics, according to bait type and fishing location, Annapolis River creel survey, 1975.

Bait type	Fishing location: Upriver — Angler[1] No.	%	Total effort (hr)[2]	Total catch	Av. hours per angler	Av. fish per angler	Av. hours per fish	Causeway — Angler[1] No.	%	Total effort (hr)[2]	Total catch	Av. hours per angler	Av. fish per angler	Av. hours per fish
Alewife[3]	65	51.6	172.6	23	2.66	0.35	7.5	5	0.5	23.8	0	4.75	0	–
Alewife or herring pieces	13	10.3	29.8	2	2.29	0.15	14.9	9	0.9	12.8	0	1.43	0	–
Plugs	23	18.3	61.0	6	2.65	0.26	10.2	207	19.7	412.8	10	1.99	0.05	20.7
Bucktail	10	7.9	6.8	0	0.68	0	–	742	70.6	1,553.6	77	2.09	0.10	9.6
Other lures and bait	15	11.9	19.7	0	1.31	0	–	88	8.4	195.6	0	2.22	0	–

[1]Only anglers whose bait type was recorded are included.

[2]Time fishing includes total time reported and observed.

[3]Whole fish, live or dead.

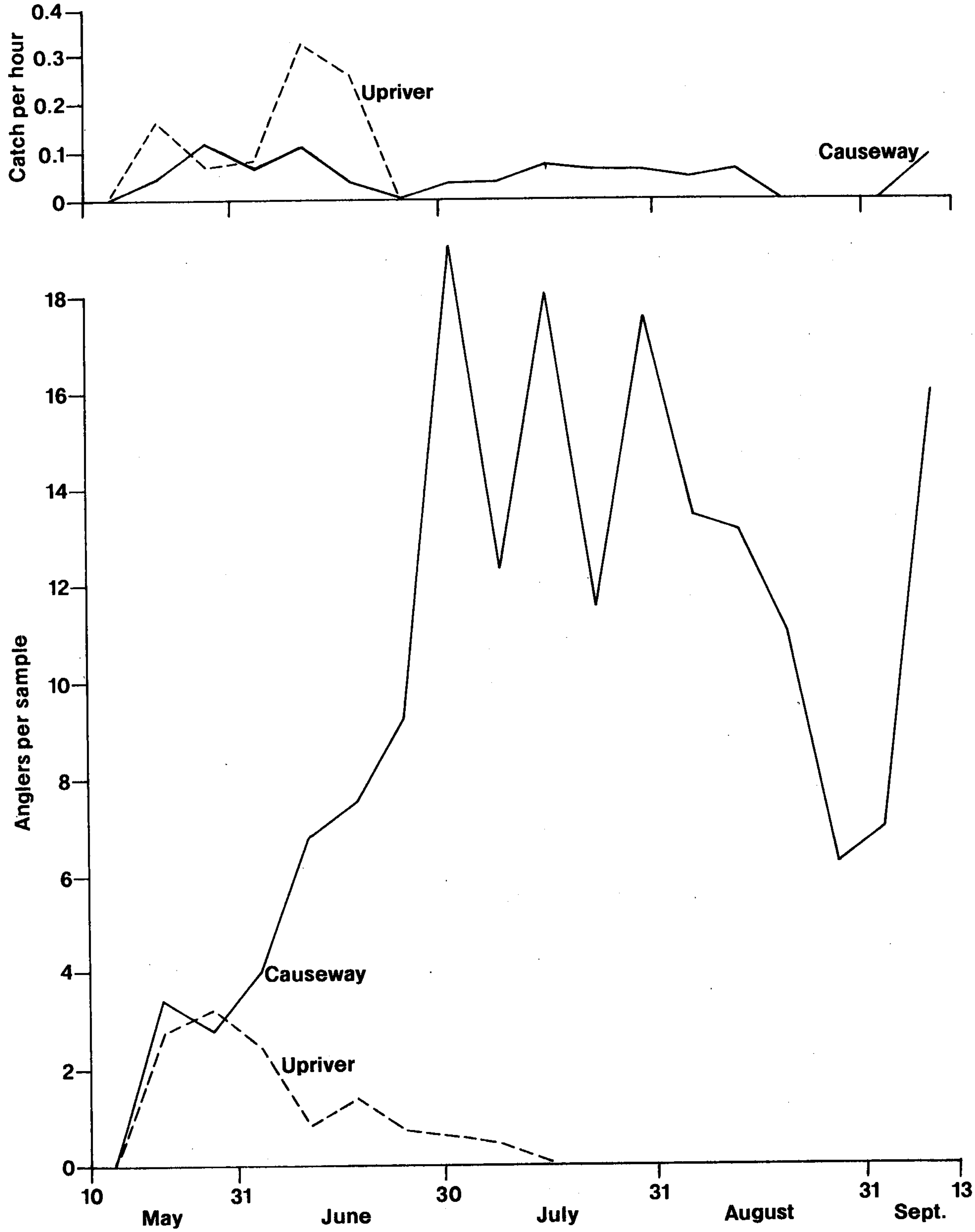


FIG. 3. Anglers per sample and catch per hour in the striped bass sport fishery at the upriver and causeway sites, Annapolis River, 1975.

TABLE 5. Number of anglers at the causeway, by origin and time of week, Annapolis River creel survey, 1975.

Time of week	Origin: Annapolis County No.	%	Kings County No.	%	Non-local No.	%	Total No.	%	No. of samples	No. anglers per sample
Weekend & holiday	104	9.9	73	6.9	233	22.1	410	38.9	42	9.8
Weekday	130	12.3	77	7.3	437	41.5	644	61.1	53	12.2

Fishing pressure did not vary significantly ($P<0.05$) between days of the week at either the upriver or causeway sites (Table 6), when considered over the entire survey period (May 13-September 11 at the causeway and May 13-July 7 at the upriver sites). The period is shorter for the upriver sites because no anglers were observed fishing there after July 7.

TABLE 6. Fishing pressure by location and day of the week, Annapolis River creel survey, 1975.

Day	Upriver[1] No. of samples	No. anglers per sample	Standard deviation	Causeway[2] No. of samples	No. anglers per sample	Standard deviation
Monday	8	1.6	2.13	12	12.4	9.47
Tuesday	11	1.1	1.30	16	10.4	7.02
Wednesday	10	0.5	0.97	11	10.8	10.58
Thursday	8	2.2	3.33	12	11.8	7.55
Friday	12	1.1	1.93	14	9.7	7.33
Saturday	17	1.4	2.29	16	10.5	5.75
Sunday	18	2.1	3.64	18	10.1	7.59

[1]May 13 to July 7.

[2]May 13 to September 11.

Fishing activity was greatest during daylight hours, both at upriver sites and the causeway, with the peak of daylight activity occurring in the early evening (Table 7). At upriver sites, little overnight fishing occurred, although it was fairly popular at the causeway.

Anglers were most likely to be successful during afternoon fishing at upriver sites, while at the causeway fishing was best during the early morning hours. However, the high early-morning catch rate is probably overstated, due to inclusion of fish caught the previous night or prior to 0500 hours. Large numbers of anglers fished the causeway during midday when fishing success was usually low. Upriver, there was a tendency for more anglers to be present when the fishing was good; that is, word of good fishing spread quickly, drawing more anglers when it occurred.

TABLE 7. Fishing pressure and catch per unit of effort by location and time period, Annapolis River creel survey, 1975.

Location	Time period	No. of samples	Anglers per sample	Standard deviation	Catch per hour
Upriver[1]	0500–0900	16	0.50	0.816	0.111
	0900–1300	20	1.05	2.282	0.086
	1300–1700	17	1.71	3.016	1.196
	1700–2100	17	2.71	2.827	0.104
	2100–0100	15	1.33	2.498	0.107
Causeway[2]	0500–0900	20	5.00	4.963	0.088
	0900–1300	19	11.79	6.571	0.020
	1300–1700	23	11.57	7.121	0.030
	1700–2100	18	16.00	8.146	0.048
	2100–0100	20	9.50	7.287	0.058

[1]May 13 to July 7.

[2]May 13 to September 11.

The data are insufficient to permit assessment of the influence of the tidal cycle on fishing activity or success, but general observations indicate that anglers preferred to fish the discharge side of the causeway, particularly in the hour or so following the change in flow direction. This change occurs several hours prior to attainment of the tidal extreme.

Simulated Sampling Designs and their Efficiencies

The randomization method employed for allocating samples to sampling units permits higher probabilities of selection to be applied to locations that experience more variability in fishing effort. The procedure does not control the number of observations per location but only the corresponding probabilities. This makes little difference when the expected allocation is large, but fluctuations in the randomizing mechanism become increasingly important as the expected allocation decreases, and are serious when less than five observations are assigned to a location. The differences in expected allocation between sites were large, particularly for main sites such as the causeway and Paradise; but there were undesirably few observations at Paradise and at other upriver sites in May and June. The stratified estimates of total catch and effort were thus based on the 1975 allocation rather than on the probabilities in the allocating mechanism. The Horvitz-Thompson estimates (Horvitz and Thompson 1952), however, utilized the allocation probabilities. They are calculated by dividing each observation by its probability of selection and summing.

Analysis of Catch and Effort Data

Effort (hours fished) and catch per unit effort (CPE in fish per hour) for individual trips were examined. Although the mean efforts per trip for complete and incomplete trips were nearly equal (2.097 vs 2.061, unweighted), mean CPE by trips for completed trips was 0.059 fish per hour, almost twice as high as the value 0.032 obtained for incomplete trips. The large difference between complete and incomplete trips, together with the difficulty of assigning the catch from an incomplete trip to a unique point in time, necessitated the use of reported catch only from complete trips in further analysis. Total observed effort during a sampling period, including both complete and incomplete trips, was used in further analysis. Total observed catch would have been a more desirable variable than reported catch for complete trips, but was unavailable due to the field procedures.

The variables chosen and methods of analysis employed ensure unbiased estimates for total catch and effort at the sites sampled, during the period May 13-September 11, from trips completed between 0500 hours and 0100 hours the following day.

Two approaches to the analysis were pursued. The first method ignored auxiliary information on location, date, etc., and constructed estimates of catch and effort by the method of Horvitz and Thompson (1952). The Horvitz-Thompson estimate of total catch was 872 fish, with a confidence interval (±2 standard deviations) of 520 ≤ total catch ≤ 1,225. The Horvitz-Thompson estimate of total effort was 12,663 hours, with confidence interval 9,920 ≤ total effort ≤ 15,400. Similar estimates were also obtained for the population variance for catch, 0.650 fish^2/trip^2, and for effort, 63.657 hours^2/trip^2. These latter estimates were used to compare the efficiency of various schemes with simple random sampling.

The second method was to consider the data as a stratified random sample. In this case, the estimates were based on the 1975 allocation of samples to strata, rather than the allocation probabilities arising from Table 1. The method employed to allocate samples to sampling units does not control the number of observations per location directly, but only indirectly through the corresponding probabilities. As mentioned previously, this makes little difference when the expected allocation is large. Thus, the success of the 1975 allocation and not the allocation scheme is considered.

Two stratifications are considered. Stratification "A" makes detailed use of the natural classification of the data, with strata consisting of combinations of location, month, and weekdays (Tables 8 and 9). The stratified estimate of total catch was 1,117 fish, of which 469 were caught at the causeway, 648 upstream, and 0 at the Bear and Allain rivers (Table 8). For total effort, the estimate is 13,114 hours — 9,466, 3,541 and 107 hours, respectively (Table 9). Confidence limits (±2 standard deviations) can be set at 500-1,500 fish for total catch and 10,000-15,000 hours for total effort. Since upriver catch and effort are poorly estimated and two observations make large contributions, confidence intervals are unwarranted.

The single observation at Paradise for weekends and holidays in June contributed 440 fish to the estimated catch. In May and June, the variances for Paradise for weekdays and for weekends and holidays, as well as those for Tupper Brook for weekends and holidays, were equated, since one observation is insufficient to estimate a within-stratum variance.

The observations for Paradise for weekdays in May and weekends and holidays in June account for more than a third of the variance estimates for overall catch and almost two-thirds of the variance estimates for the upriver catch. Pooling the months May and June, while retaining the distinction between weekdays and weekends, reduces the estimated catch of Paradise by 240 fish and decreases the contribution of Paradise to the variance estimates for catches by about 25%. Revised catch estimates for this method would be 877 fish in total, of which 408 were caught upstream and 469 caught at the causeway. The Horvitz-Thompson estimate of total catch is in agreement with this lower estimate.

With these data, variance estimates appear related to the corresponding means, so that choosing an estimation method to minimize the variance after examining the data is likely to bias the total downward. Since errors of omission (i.e., totals applying only to sites included in the survey and to the calendar interval May 13-September 11, and non-inclusion of trips completed from 0100 to 0500 hours) tend to underestimate catch and effort, the introduction of additional downward bias by striving for the shortest confidence intervals seems unwarranted. The problem is basically how to treat the two single observations at Paradise.

Finite population correction factors were not used, even though some strata had fairly high rates of sampling. In view of the contributions of the Paradise observations, their effect would be a marginal decrease in the variance estimates.

TABLE 8. Estimates of total catch and variance, stratified by month, location and day (Stratification "A"), by striped bass anglers, Annapolis River creel survey, 1975.

Location	May				June				July				August - September				Stratum totals
	Weekdays (65)[1]		Others (30)[1]		Weekdays (105)[1]		Others (45)[1]		Weekdays (110)[1]		Others (45)[1]		Weekdays (145)[1]		Others (65)[1]		
	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	
Mean catch																	
Causeway	0.143	7	0.167	6	0.167	6	0.556	9	1.588	17	0.667	6	1.267	30	0.368	19	469.19
Trailer park	0.0	2	0.0	3	0.0	3	0.0	7	0.0	1	0.0	4	0.0	1	0.0	6	0.0
Midway	0.0	2	0.0	2	0.0	7	0.0	3	0.0	8	0.0	4	0.0	4	0.0	7	0.0
Bridgetown	0.0	3	0.0	2	0.250	4	0.0	1	0.0	2	0.0	4	0.0	3	0.0	3	26.25
Paradise	4.0	1	1.333	3	0.444	9	4.0	1	0.0	4	0.0	5	0.0	7	0.0	7	526.61
Tupper Brook	1.0	2	0.0	1	0.200	5	0.2	5	0.0	7	0.0	4	0.0	5	0.0	1	95.00
Round Hill	0.0	1	0.0	2	0.0	2	0.0	4	0.0	3	0.0	2	0.0	3	0.0	3	0.0
Bear & Allain rivers	0.0	4	0.0	1	0.0	1	0.0	4	0.0	2	0.0	3	0.0	1	0.0	6	0.0
																	1,117.05
Variance																	
Causeway	0.143	7	0.167	6	0.167	6	1.020	9	5.757	17	0.667	6	5.168	30	1.023	19	8,821.65
Trailer park	0.0	2	0.0	3	0.0	3	0.0	7	0.0	1	0.0	4	0.0	1	0.0	6	0.0
Midway	0.0	2	0.0	2	0.0	7	0.0	3	0.0	8	0.0	4	0.0	4	0.0	7	0.0
Bridgetown	0.0	3	0.0	2	0.250	4	0.0	1	0.0	2	0.0	4	0.0	3	0.0	3	689.06
Paradise	0.778	1	5.333	3	0.778	9	5.333	1	0.0	4	0.0	5	0.0	7	0.0	7	16,639.30
Tupper Brook	2.0	2	0.200	1	0.200	5	0.200	5	0.0	7	0.0	4	0.0	5	0.0	1	4,927.00
Round Hill	0.0	1	0.0	2	0.0	2	0.0	4	0.0	3	0.0	2	0.0	3	0.0	3	0.0
Bear & Allain rivers	0.0	4	0.0	1	0.0	1	0.0	4	0.0	2	0.0	3	0.0	1	0.0	6	0.0
																	31,077.01[2]

[1] Total number of samples possible.

[2] Standard deviation of stratum totals = 176.29

TABLE 9. Estimates of total fishing effort and variance, stratified by month, location and day (Stratification "A"), by striped bass anglers, Annapolis River creel survey, 1975.

	May				June				July				August-September				
	Weekdays (65)[1]		Others (30)[1]		Weekdays (105)[1]		Others (45)[1]		Weekdays (110)[1]		Others (45)[1]		Weekdays (45)[1]		Others (65)[1]		
Location	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Value	No. of samples	Stratum totals
Mean effort																	
Causeway	1.761	7	3.833	6	4.195	6	12.233	9	25.676	17	26.625	6	21.614	30	16.751	19	9,465.745
Trailer park	0.625	2	0.0	3	0.0	3	0.0	7	0.0	1	0.0	4	0.0	1	0.0	6	40.63
Midway	0.0	2	2.083	2	1.739	7	0.167	3	0.0	8	0.125	4	0.0	4	0.0	7	258.23
Bridgetown	0.0	3	0.0	2	1.125	4	0.0	1	0.750	2	0.0	4	0.0	3	0.0	3	200.63
Paradise	17.58	1	5.470	3	5.425	9	11.5	1	0.0	4	1.45	5	0.0	7	0.0	7	2,464.11
Tupper Brook	0.415	2	5.250	1	1.200	5	3.934	5	0.0	7	0.0	4	0.0	5	0.0	1	487.51
Round Hill	0.0	1	3.00	2	0.0	2	0.0	4	0.0	3	0.0	2	0.0	3	0.0	3	90.00
Bear & Allain rivers	0.0	4	0.0	1	0.0	1	0.350	4	0.0	2	1.333	3	0.0	1	0.487	6	107.39
																	13,114.25
Variance																	
Causeway	6.251	7	20.743	6	16.641	6	123.09	9	194.283	17	212.034	6	431.487	30	100.721	19	599,785.0
Trailer park	0.781	2	0.0	3	0.0	3	0.0	7	0.0	1	0.0	4	0.0	1	0.0	6	1,649.86
Midway	0.0	2	3.646	2	8.987	7	0.083	3	0.0	8	0.063	4	0.0	4	0.0	7	15,883.1
Bridgetown	0.0	3	0.0	2	5.063	4	0.0	1	1.125	2	0.0	4	0.0	3	0.0	3	20,761.1
Paradise	26.944	1	11.131	3	26.944	9	11.131	1	0.0	4	3.95	5	0.0	7	0.0	7	174,324.0
Tupper Brook	0.344	2	23.692	1	2.419	5	23.692	5	0.0	7	0.0	4	0.0	5	0.0	1	36,978.7
Round Hill	0.0	1	18.0	2	0.0	2	0.0	4	0.0	3	0.0	2	0.0	3	0.0	3	8,100.0
Bear & Allain rivers	0.0	4	0.0	1	0.0	1	0.612	4	0.0	2	5.333	3	0.0	1	0.569	6	4,310.27
																	861,792.03[2]

[1]Total number of samples possible.

[2]Standard deviation of stratum totals = 928.33

Stratification "B" (Table 10) considered the effects of time of day, day of week, month, location and stage of tide on catch and effort. Fortunately, catch and effort appeared to be proportionally related so that an efficient stratification for effort is also good for catch.

Over short calendar intervals, the stage of the tide is confounded with the time of day so that the effects of one are difficult to separate from those of the other. However, in the calendar interval of the study, no consistent influence of the tide was evident so that tide was considered no further.

When time of day and day of week were considered together over all sites, it appeared that weekends have an average effort and catch only half as big as those of weekdays. The estimated standard deviation was also half as big. Closer examination revealed that this was not a consistent pattern through the calendar interval and resulted from the heavy weekday fishing at the causeway in August. The differences between weekdays and weekends were thus ignored. There appears to be less effort and catch early in the day, but the trends were not sufficiently large and consistent to be of use in stratifications.

Location was by far the most important of the variables considered, explaining 42% of the variance in effort and 9% of the variance in catch. The inclusion of all combinations of months and locations explained 53% of the variation in effort and 16% of the variation in catch.

Examination of the time of day when fish were caught in relation to the date (Table 11) indicated that when both upriver and causeway site data are combined trips in periods 3-5 in May-June; 1-3 and 5 in July; 1 and 5 in August; and 1, 4 and 5 in September were more successful than those in other time periods. This represents a steady trend of successful fishing from late afternoon and evening during May, to mid-day in July, then to late afternoon again in September. Some of the fish reported in the 0500-0900 hour sample period were caught earlier in the morning or perhaps even late the previous night.

Stratification "B" (Table 10) was constructed on the basis of the above trend, together with location and month. The trailer park, Round Hill, Bear and Allain river sites were omitted since they represented only 2% of the stratified effort, as estimated by the first design, and 0% of the catch. Their contribution is comparable to the unknown contribution of trips ending from 0100-0500 hours and less than that due to fishing outside the observed calendar interval.

This stratification was fairly effective, estimating total catch and effort values of 813 fish and 12,675 hours (Table 10), of which 335 and 478 fish were caught and 1,986 and 10,689 hours were fished at the upriver and causeway sites, respectively. However, it did not handle well the rapid changes in time of day of successful trips in July and August. The correlation between

TABLE 10. Catch and effort statistics stratified by location, month and time of day (Stratification "B"), Annapolis River creel survey, 1975.

			Stratum totals					
Location[1]	Month[2,3]	Time[4]	Catch	Variance	Effort	Variance	1975 allocation	Optimum allocation[5]
1	May-June	3,4,5	68.6	1,001.22	1,288.9	139,523.5	15	32
1	May-June	1,2	7.5	56.89	294.6	8,914.0	13	8
5	May-June	3,4,5	235.2	7,299.52	1,060.8	71,260.0	10	18
5	May-June	1,2	0.0	—	553.2	74,771.9	4	13
3,4,6	May-June	3,4,5	80.3	2,218.85	820.3	88,347.4	22	31
3,4,6	May-June	1,2	19.7	386.08	279.3	1,352.8	15	10
1	July	2,3	79.7	1,158.69	1,539.3	59,861.0	14	26
1	July	1,4,5	134.3	5,312.41	2,569.6	155,616.6	9	34
3,4,5,6	July	2,3	0.0	—	86.8	7,534.2	10	8
3,4,5,6	July	1,4,5	0.0	—	76.3	2,817.1	28	8
1	Aug-Sept	4,5	99.3	1,332.94	1,822.0	63,488.9	22	34
1	Aug-Sept	1,2,3	88.7	1,981.56	2,284.4	232,726.9	27	72
3,4,5,6	Aug-Sept	4,5	0.0	—	0.0	—	14	0
3,4,5,6	Aug-Sept	1,2,3	0.0	—	0.0	—	24	0
Totals			813.3	20,748.20	12,675.5	918.714.2		

[1]Locations coded as: 1, causeway; 3, midway; 4, Bridgetown; 5, Paradise; and 6, Tupper Brook.

[2]Months coded as: 1, January; 2, February; etc.

[3]Days in May-June = 49, July = 31, August-September = 42.

[4]Time coded as: 1, 0500-0900 hours; 2, 0900-1300 hours; etc.

[5]Optimum allocation for effort.

stratum means of catch and effort was $R^2 = 0.67$. This correlation could likely have been improved if a slightly different relation between time of day of fish capture and month had been used. Table 11 shows the relationship for both upriver and causeway sites. Averaging the data produces a trend differing from the one shown.

TABLE 11. Relationship between time of day of striped bass capture (n=131) and month, Annapolis River creel survey, 1975.

Time period	Time	Numbers of fish caught: Upriver May	Upriver June	Causeway May	Causeway June	Causeway July	Causeway August	Causeway September
1	0500-0900	0	1	1	0	8	12	4
2	0900-1300	0	4	0	0	8	1	0
3	1300-1700	2	6	0	1	14	0	2
4	1700-2100	4	8	1	6	4	2	8
5	2100-0100	4	2	0	1	8	13	6
Totals		10	21	2	8	42	28	20
Mean time period (upriver and causeway areas combined).				3.9	3.5	2.9	3.1	3.6

Increases in the number of strata in Stratification "B", which was used for optimal allocation, were not considered for three reasons:

1. Since within-stratum variances were not equal, optimal allocation would not be possible with the few observations available. Unless stratum contributions to the total variance are nearly equal, each stratum should have more than 1 or 2 observations.

2. The within-stratum variances are estimated. The percentage variance in these estimates increases as the number of strata increases, so that variance due to estimated optimal allocation differing from "true" optimal allocation also increases.

3. As the number of strata increases, the survey design starts to explain the pecularities of the 1975 data and becomes vulnerable to a shift in the annual pattern of fishing.

Estimates of total catch and effort calculated by the three methods used are compared (Table 12). The Horvitz-Thompson and Stratification "B" estimates are perhaps the most reliable.

TABLE 12. Three estimates of total catch and effort, by location, Annapolis River creel survey, 1975.

Method	Location	Effort (hours)	Standard deviation	Catch (fish)	Standard deviation
Horvitz-Thompson	Combined	12,663	1,370.0[1] 7.98[2]	872	177.1[1] 0.81[2]
Stratification "A"	Upstream	3,598	774.5	469	93.9
	Causeway	9,466	507.6	648	131.6
	Other sites	107	65.7	0	0
	Combined	13,171	928.3	1,117	176.3
Stratification "B"	Upstream	2,876	494.8	335	99.5
	Causeway	9,799	812.5	478	104.1
	Other sites[3]	—	—	—	—
	Combined	12,675	951.3	813	144.0

[1]Estimated variation.

[2]Population variation.

[3]Not estimated because of low significance.

The estimated variances and relative efficiencies of estimates of catch and effort are compared (Table 13) for three sampling designs: (a) simple random sampling of eight sites (Bear and Allain rivers combined); (b) Stratification "A", with the 1975 allocation; and (c) Stratification "B", with optimum (Neyman) allocation of monthly sampling effort.

TABLE 13. Relative efficiency of three sampling designs and the Horvitz-Thompson method for estimating total catch and effort, Annapolis River creel survey, 1975.

Design	Catch		Effort	
	Variance	Relative efficiency	Variance	Relative efficiency
Simple random	52,651	1.0	5,156,300	1.0
Horvitz-Thompson	31,350	1.68	1,877,000	2.75
Stratification "A"	31,077	1.69	861,792	5.98
Stratification "B"	10,407	5.06	447,017	11.53

Stratification "A", with 1975 allocation, is estimated to be six times as efficient for effort and 1.7 times as efficient for catch as simple random sampling. Optimum allocation with Stratification "B" is nearly twice as efficient again.

Age and Growth

Between May 13 and September 11, a total of 215 angler-caught striped bass was sampled. Their mean fork length was 65.98 cm and the mean weight of 191 fish was 3.95 kg. Two peaks occurred in the length-frequency distribution, one at 55.0-57.9 cm, the other at 76.0-78.9 cm (Table 14). Mean lengths and weights varied between months, but not significantly ($P<0.05$), with the largest fish being caught in June and August (Table 15).

TABLE 15. Mean lengths and weights of 215 striped bass by month, sexes combined, Annapolis River creel survey, 1975.

Month	No. of fish[1]	Mean length (cm)	Standard deviation	No. of fish[1]	Mean weight (kg)	Standard deviation
May	17	64.56	13.436	13	2.955	1.843
June	30	66.53	19.975	28	4.773	4.140
July	88	63.11	12.625	76	3.473	2.490
August	46	71.98	15.380	40	5.048	3.148
September	34	65.51	10.717	34	3.435	1.670

[1]Numbers of fish vary due to incomplete data.

The sex ratio of 205 fish was 1:3 (male:female). There was no significant difference ($P<0.05$) between the sex ratios of fish caught upriver or at the causeway. Difficulty was experienced in determining the maturation state of some fish. Few fish were spent or appeared to be potential spawners in the present year; most were mature fish undergoing gonad development preparatory to spawning in future years. Three fish were too immature to determine their sex; one female contained three distinct ovaries and one fish was apparently hermaphroditic.

The length-weight relationships of male and female striped bass were, respectively, $\log W=2.8975(\log L)-4.7447$ ($r=0.99$; $n=35$) and $\log W=2.9288(\log L)-4.7959$ ($r=0.99$; $n=146$), where W is weight in kilograms and L is fork length in centimetres. Male striped bass longer than 82 cm were uncommon and the largest fish were female (Table 14). Female and male fish had similar weights for a given length.

No significant differences were found in the mean fork

TABLE 14. Length-frequency and length-weight distribution of 181 striped bass, Annapolis River creel survey, 1975.

Fork length (cm)	Male			Female			Sexes combined		
	Number of fish	Mean weight (kg)	Standard deviation	Number of fish	Mean weight (kg)	Standard deviation	Number of fish	Mean weight (kg)	Standard deviation
43.0-45.9	4	1.130	0.2289	1	1.100	—	5	1.124	0.1987
46.0-48.9	4	1.320	0.2197	8	1.367	0.1190	12	1.352	0.1507
49.0-51.9	3	1.580	0.1539	11	1.584	0.1786	14	1.583	0.1679
52.0-54.9	1	1.78	—	10	1.912	0.2530	11	1.900	0.2433
55.0-57.9	4	2.020	0.1479	19	2.118	0.1602	23	2.092	0.1592
58.0-60.9	3	2.347	0.0808	14	2.349	0.1708	17	2.348	0.1566
61.0-63.9	5	2.840	0.2102	9	2.922	0.2363	14	2.893	0.2228
64.0-66.9	0	—	—	6	3.393	0.2727	6	3.393	0.2727
67.0-69.9	0	—	—	4	3.690	0.2600	4	3.690	0.2600
70.0-72.9	2	4.560	—	8	4.418	0.4092	10	4.446	0.3664
73.0-75.9	4	4.820	0.1766	9	4.460	0.4658	13	4.571	0.4271
76.0-78.9	2	4.880	—	18	5.397	0.4338	20	5.346	0.4409
79.0-81.9	1	6.50	—	6	5.768	0.4714	7	5.873	0.5116
82.0-84.9	0	—	—	4	6.590	0.2859	4	6.590	0.2859
85.0-87.9	1	8.10	—	3	7.697	0.6573	4	7.798	0.5733
88.0-90.9	0	—	—	6	8.305	0.5428	6	8.305	0.5428
91.0-93.9	0	—	—	2	9.800	—	2	9.800	—
94.0-96.9	1	9.78	—	2	11.350	—	3	10.827	1.2426
97.0-99.9	0	—	—	1	9.680	—	1	9.68	—
100.0-102.9	0	—	—	2	14.150	—	2	14.150	—
103.0-105.9	0	—	—	2	14.150	—	2	14.150	—
106.0-108.9	0	—	—	1	14.50	—	1	14.50	—

lengths of striped bass angled at the causeway or upriver, for either sex.

Ages ranged from 3 to 18 years with 62% of the fish being in age group 4-8 and a further 21% in age group 10-12 (Table 16).

TABLE 16. Mean length (n=203) and weight (n=189) by age for combined sexes of striped bass, Annapolis River creel survey, 1975.

Age	No. of fish	Length (cm) Mean	Range	Standard deviation
3	5	43.50	41.50-44.50	1.173
4	25	49.12	44.50-55.00	2.339
5	35	53.89	46.00-62.50	3.720
6	31	58.94	52.00-67.00	3.547
7	27	64.19	56.00-79.00	5.485
8	8	71.50	62.00-77.00	5.484
9	9	74.89	70.00-84.50	4.197
10	20	75.55	71.00-86.00	3.612
11	9	77.22	72.50-88.00	4.823
12	14	81.29	72.00-91.00	5.370
13	7	85.64	73.00-97.50	9.1729
14	5	87.30	77.00-90.50	6.0374
15	4	96.00	92.00-103.00	4.966
16	3	97.00	89.00-102.00	7.000
17	1	102.00	—	—
18	1	106.00	—	—

Age	No. of fish	Weight (kg) Mean	Range	Standard deviation
3	5	1.032	0.90-1.14	0.0955
4	22	1.505	1.10-1.88	0.1979
5	32	1.962	1.20-2.88	0.4160
6	26	2.416	1.52-3.92	0.5371
7	24	3.180	2.04-4.82	0.8409
8	7	4.017	2.90-5.70	1.0050
9	8	4.930	4.18-6.28	0.6387
10	19	4.935	4.00-6.50	0.5969
11	8	5.465	4.60-7.50	1.0080
12	10	6.520	5.40-8.10	1.1422
13	6	7.605	4.64-10.50	2.4178
14	4	7.560	6.12-8.86	1.658
15	4	11.875	9.76-15.70	2.7899
16	3	11.543	8.43-13.90	2.8124
17	1	14.400	—	—
18	1	14.500	—	—

Abundance declines rapidly with increasing age after age 12. Age estimation was more difficult with advanced age, primarily because of crowding of annuli near the scale edge and increased obscurity of annuli near the focus due to increasing thickness of the scale.

Mean lengths and weights increased regularly with age for both sexes except after age 12, when the trend became irregular (Tables 17 and 18). Nonetheless, the age-length relationship was surprisingly linear over the observed range (Fig. 4). From age 0 to age 3, the mean annual increase in length for the combined sexes was 14.8 cm. Between ages 3 and 13, mean annual length increment was 4.1 cm (range 0.7-7.3 cm), while weight annually increased 0.65 kg (range 0.05-1.09 kg). Relative annual growth in length exceeded weight increases for fish up to six years old, then weight began to increase more rapidly until a break in the growth trend occurred between ages 8 and 10 (Fig. 4). After 10 years of age, weight generally increased more rapidly with increasing age than did length.

Organochloride and Mercury Content

Ovarian tissue samples from 18 angled striped bass ranging in length from 47.0 to 103 cm were analysed for PCB and DDT (including DDD and DDE) content (Table 19). The mean PCB concentration was 3.66 ppm (range 0.08-12.8 ppm) by wet weight and for DDT was 1.75 ppm (range (0.005-6.67 ppm).

Since the logarithm of weight (log W) appeared linearly related to length (L), with $\log W = -1.5273 + 0.04156L$, ($r^2=0.99$), the relationships between length and concentrations of PCB and DDT were examined and found to be $\log PCB = -3.919 + 0.575L$ ($r^2=0.39$), and $\log DDT = -8.782 + 0.1074L$ ($r^2=0.65$). DDT and PCB concentrations were related by $\log DDT = -1.337 + 1.314 \log PCB$ ($r^2=0.83$).

Fish lacking length or weight measurements were excluded. Fish number 16 was an outlier for the PCB vs DDT and length vs PCB relation, and the correlations would have greatly improved had its values corresponded with the others.

Mercury analyses were made on the caudal musculature of seven striped bass ranging in weight from 1.75 to 5.24 kg (Table 20). Mercury concentration averaged 0.28 ppm (range 0.11-0.43 ppm).

TABLE 17. Mean length of 187 striped bass by sex and age, Annapolis River creel survey, 1975.

	Male				Female			
	No. of	Length (cm)		Standard	No. of	Length (cm)		Standard
Age	fish	Mean	Range	deviation	fish	Mean	Range	deviation
3	3	44.00	43.5-44.5	0.500	1	44.00	—	—
4	6	48.40	44.5-51.5	2.760	16	49.10	46.0-55.0	2.312
5	3	49.33	46.0-55.0	4.933	32	53.97	48.0-62.5	3.547
6	5	58.20	53.0-63.5	4.132	25	58.94	52.0-67.0	3.498
7	7	59.57	56.0-62.0	2.244	20	65.80	60.0-79.0	5.384
8	0	—	—	—	8	71.50	62.0-77.0	5.484
9	0	—	—	—	9	74.89	70.0-84.5	4.197
10	7	76.64	71.0-86.0	5.031	13	74.96	71.5-77.5	2.634
11	1	72.50	—	—	7	78.36	73.5-88.0	4.905
12	2	74.50	72.0-77.0	3.536	12	82.42	76.0-91.0	4.814
13	3	77.83	73.0-84.0	5.620	4	91.50	86.0-97.5	6.364
14	0	—	—	—	5	87.30	77.0-92.0	6.037
15	0	—	—	—	4	96.00	92.0-103.0	4.966
16	0	—	—	—	2	94.50	89.0-100.0	7.778
17	0	—	—	—	1	102.00	—	—
18	0	—	—	—	1	106.00	—	—

TABLE 18. Mean weight of 172 striped bass by sex and age, Annapolis River creel survey, 1975.

Age	Male				Female			
	No. of fish	Weight (kg)		Standard deviation	No. of fish	Weight (kg)		Standard deviation
		Mean	Range			Mean	Range	
3	3	1.027	0.90-1.14	0.1205	1	1.100	—	—
4	6	1.480	1.10-1.75	0.2180	13	1.495	1.18-1.88	0.2079
5	3	1.473	1.20-1.84	0.3301	28	1.984	1.34-2.88	0.3700
6	4	2.245	1.78-3.00	0.5318	21	2.409	1.52-3.92	0.5259
7	7	2.469	2.04-2.98	0.3009	17	3.474	2.42-4.82	0.8182
8	0	—	—	—	7	4.017	2.90-5.70	1.0050
9	0	—	—	—	8	4.930	4.18-6.28	0.6387
10	6	5.077	4.52-6.50	0.7182	13	4.870	4.00-5.90	0.5523
11	1	4.600	—	—	6	5.780	4.68-7.50	0.9714
12	0	—	—	—	10	6.520	5.40-8.10	1.1422
13	2	4.800	4.64-4.96	0.2263	4	9.007	7.40-10.50	1.3632
14	0	—	—	—	4	7.560	6.12-8.86	1.1658
15	0	—	—	—	4	11.875	9.76-15.7	2.7899
16	0	—	—	—	2	11.165	8.43-13.90	3.8679
17	0	—	—	—	1	14.400	—	—
18	0	—	—	—	1	14.500	—	—

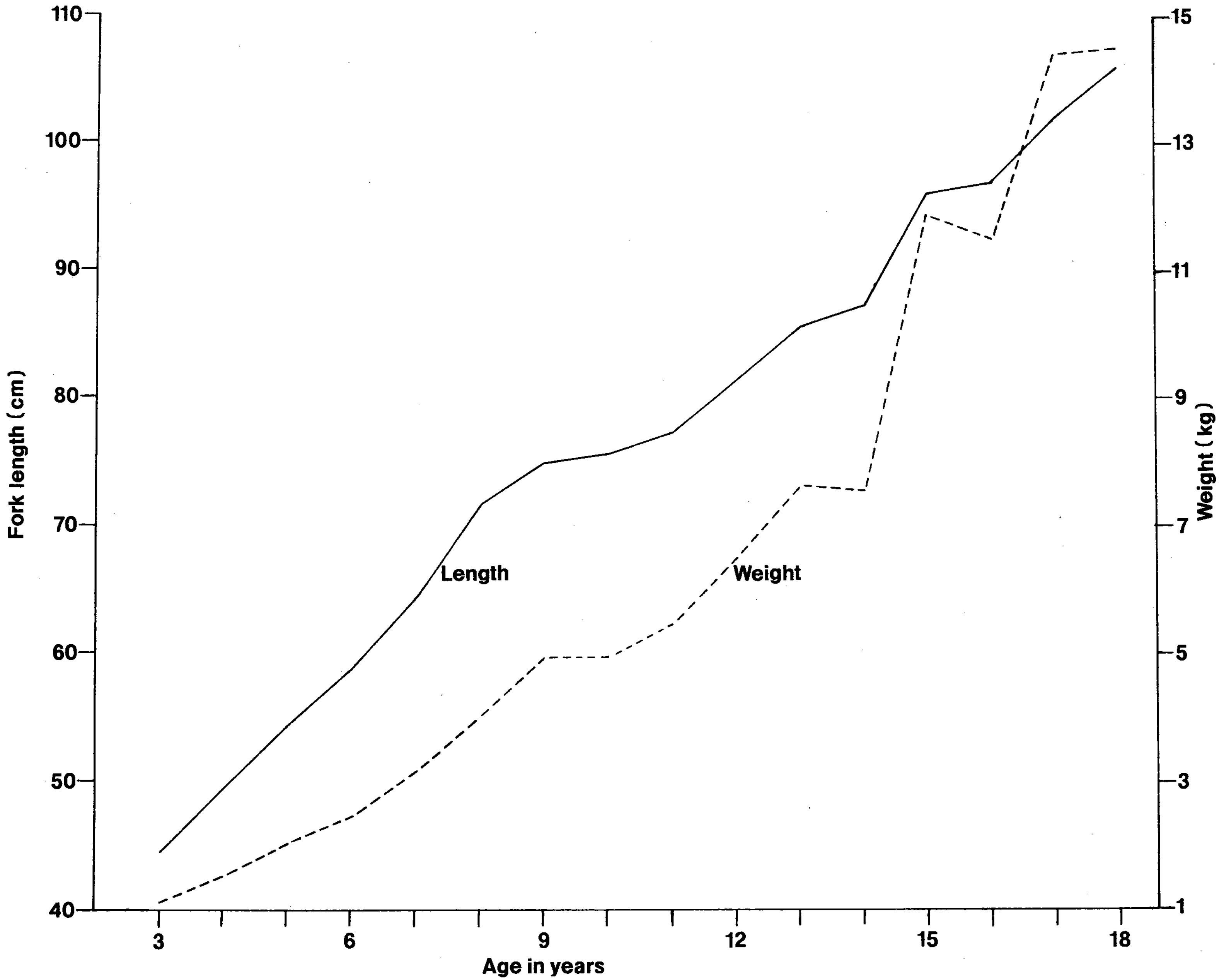


FIG. 4. Age-length and age-weight relationships for striped bass (sexes combined) from the Annapolis River, 1975.

TABLE 19. Organochloride residues in gonads of 18 female striped bass from the Annapolis River, 1975.

Fish No.	Fork length (cm)	Weight (kg)	PCB (ppm)	DDT (ppm)
1	47.0	1.38	0.15	0.01
2	53.0	1.78	0.48	0.04
3	53.5	2.16	2.89	0.74
4	53.5	2.14	0.36	0.04
5	56.5	2.48	0.08	0.005
6	57.0	2.06	0.40	0.05
7	65.5	—	5.41	0.60
8	72.0	5.06	4.62	1.63
9	72.0	4.44	0.19	0.04
10	76.0	5.00	5.39	1.17
11	77.0	5.70	2.47	1.04
12	78.0	5.34	4.50	3.64
13	88.5	8.92	12.80	6.67
14	—	9.76	1.75	0.84
15	91.0	—	8.03	4.57
16	94.0	9.80	0.33	1.56
17	100.0	13.45	5.20	4.09
18	103.0	15.70	10.80	4.68
Mean			3.66	1.75
Range			0.08-12.8	0.005-6.67

TABLE 20. Mercury content in body musculature of seven striped bass from the Annapolis River, 1975.

Sample number	Fish length (cm)	Fish weight (kg)	Mercury level (μg/g)
1	62.0	2.60	0.33±0.02
2	59.5	2.30	0.21±0.01
3	58.0	2.20	0.36±0.01
4	51.0	1.75	0.11±0.02
5	≃53	2.10	0.18±0.01
6	58.5	2.40	0.34±0.04
7	≃80	5.24	0.43±0.01
Mean			0.28

DISCUSSION AND CONCLUSIONS

Striped bass are the focus of the major sport fishery of the Annapolis River. Anglers reportedly fish the Annapolis River from ice-out in the spring to freeze-up in the autumn. Fishing pressure tends to be concentrated at a few access areas, certain of which are particularly popular, rather than being homogenously distributed over the river basin. Early spring (April-May) fishing is concentrated upriver at sites straddling the limit of saltwater penetration, while summer and fall fishing occurs at the Annapolis Royal causeway.

Striped bass fishing below causeway at Annapolis Royal.

The majority of anglers sampled while fishing upriver in the spring of 1975 were of local origin. Tourists from other parts of Nova Scotia or outside the province formed about 63% of anglers fishing at the causeway. Approximately 36% of the anglers sampled at the causeway in 1975 were local people, compared with 64% in 1972 (Penney 1973). About 27% of the causeway anglers were tourists originating outside the province, compared with only 16% in 1972 (Penney 1973). The local economic influence from tourism related to the striped bass fishery is significant and apparently increasing. Most tourists come to Nova Scotia for reasons other than fishing striped bass, but the presence of the fishery immediately adjacent to a major highway encourages many to remain in the area to fish. Observations suggest that a fair number of visitors stay several days, particularly at a nearby campsite where fishing equipment is sold.

Most anglers failed to catch a striped bass on any given trip; only 7% of those interviewed had caught a fish when sampled. An average of 19 hours was spent fishing for each fish caught. Otto (1971) reported comparable results for the striped bass fishery of coastal Maine.

Fewer anglers fished upriver than at the causeway, but their catch rate was several times higher. This result probably relates to the concentration of spawning striped bass and their active feeding on large numbers of alewives in the confines of the river channel. The use of whole, usually live, alewives has proved to be a most effective bait.

At the causeway, the fishing success of American and Kings County anglers seems explainable in terms of fishing experience. Many Americans were striped bass fishermen with considerable previous experience, while many Kings County anglers were part of a dedicated, skillful group from a local Canadian Armed Forces base. Penney (1973) also mentions the prevalence of servicemen among the anglers.

The most successful and frequently used bait types were alewives and bucktails, at the upriver and causeway sites, respectively. Frequency of use and success of bait types seems related to environmental conditions. At the upriver sites, migrating alewives were abundant and readily caught by anglers who jigged for them. Striped bass fed actively on them and the narrow river width, shallow depth and slow flow provided a suitable environment for the drifting of live bait. The greatly fluctuating depth and flow conditions, resulting from tidal activity, and the difficulties of obtaining and using alewives in these conditions makes the weighted bucktail preferred at the causeway. In the Maine surf fishery, the most successful anglers used whole or cut fish, although seaworms (nereids, bloodworms) were most frequently used (Otto 1971).

Seasonal cycles in catch and fishing pressure roughly corresponded at the upriver sites but not at the causeway, particularly during the period late June through August. The low but steady catchability of striped bass during this period presumably reflects the movements of these fish to the causeway area while an influx to tourists dramatically increased the number of anglers. Along the Maine coast, fishing pressure and catch per hour peak during spring when striped bass collect in estuaries, then decrease during summer and autumn (Otto 1971). Unlike the Maine fishery, which experienced the greatest fishing pressure on weekends and holidays, the Annapolis River fishery showed no consistent pattern in weekday versus weekend fishing pressure except at the causeway in August, when the greatest fishing pressure was on weekdays. This pattern seems attributable to the large number of summer tourists, many of whom fished a few days then moved to another location for the weekend, since local anglers were about as numerous on weekends as on weekdays. In future creel surveys at the causeway it would be advisable to sample all days equally, since there is no evidence that catch and effort are more variable on weekends than on weekdays, and it is costly to sample more frequently on weekends. Johnson and Wroblewski (1962) note that an even distribution of census days throughout the week facilitates statistical analysis. Otto (1971) believes that weekly variations in fishing pressure reflect the availability of leisure time.

Fishing pressure was greatest during daylight hours at both upriver and causeway sites, with activity peaking in the early evening, whereas Otto (1971) reports peak fishing pressure during midday in the Maine fishery. Fishing was best during the early morning at the causeway and in Maine (Otto 1971), but was best upriver in the afternoon. It is not surprising that the patterns of fishing activity and success differ between locations, since they are influenced by factors such as local experience and tradition (which is in turn influenced by historic fishing success in relation to patterns of fish migration), present fishing success and the opportunities available to each angler for fishing.

Three estimates were made of the total catch of striped bass and the effort expended in the Annapolis River fishery. Stratification of the data in two methods improved the efficiency of analysis, while the third method utilized the allocation of probabilities of the sampling scheme (Horvitz-Thompson estimates). The stratification schemes considered the location-time interactions at several levels. Stratification "A" considered location, month and day type; and Stratification "B" considered location, month and time of day in relation to fishing success. Stratification "B" was the most efficient, and location was by far the most important of the variables, followed by month. Stage of tide was not an effective criterion, although it undoubtedly influences the fishery. Stratification according to season may be the criterion most widely applicable to a single-species fishery, but Otto (1971) reported that criteria related to convenience of access and daily and weekly fluctuations in fishing pressure were most efficient for the Maine coast striped bass fishery.

When considerable daily fluctuation in fishing pressure is expected, a creel survey should sample a large number of days if reliable estimates are to be obtained (Best and Boles 1956). For logistic reasons, this survey sampled every day of the survey period, rather than taking more samples on fewer days.

Creel surveys have used various measures of catch and effort (Carlander et al. 1958). In general, sampling plans which permit unbiased estimation of these variables are preferable to those which permit unknown and subjective biases (Robson 1960). Both reported and observed fishing effort, and catch (reported and observed combined, with perhaps most catches being observed), were recorded in this survey for complete and incomplete fishing trips. Only observed fishing effort for all trips, and catches for completed trips were analysed. The sampling scheme and information utilized in this survey should provide unbiased estimates of total catch and effort. Of the three estimates of total catch, the Horvitz-Thompson and Stratification "B" – at 872 and 813 fish respectively – are perhaps the most reliable. The three estimates of total effort are in good agreement, at approximately 12,700-13,200 hours.

Comparison of the creel survey estimates of the total catch of striped bass in the Annapolis River with estimates by Fishery Officers of the Conservation and Protection Branch indicate that their estimates – 26,525 fish for 1975; see Penney (1973) for 1951-1972 figures – are as much as 30 times greater. Reason exists, then, for doubt about the accuracy of previous angling statistics, particularly those from 1969 to 1975, when catches of 25,000-58,000 fish were reported.

Observed fishing effort is the preferred variable, since it does not overestimate the time that an angler is fishing nor his effective effort the way sample counts of anglers do (Carlander et al. 1958). The traditional ratio type estimate (which applies an estimated catch rate to the estimated total effort) – using reported catch and effort determined by interview – can be biased by interpersonal relations between anglers and interviewer, angler's recollection of trip length and number of fish caught, inclusion of lunch or rest periods in fishing time, and systematic variation between the reports of successful and unsuccessful anglers (Carlander et al. 1958). These problems may be difficult or impossible to evaluate. In this survey, a bias towards overestimation of fishing effort – particularly for those anglers fishing many hours, i.e., overnight – would have occurred, had reported rather than observed fishing effort been used. The use of observed catch eliminates potential reporting biases, but need not eliminate the opportunity to obtain life history data by examining the angler's catch or to obtain economic or personal information from the angler.

Catches for complete trips were chosen for analysis because of the large differences between catch rates for complete and incomplete trips and the difficulty in assigning the catch from an incomplete trip to a unique time. Carlander et al. (1958) consider that catch-per-hour data from complete trips may not be as representative of fishing success as data from incomplete trips, if it is collected only at major access points and at times when many fishermen are leaving. These factors were not important in this survey. An appropriate sampling scheme could minimize those hours that have few fishermen completing trips and improve sampling efficiency.

Problems of length-of-stay bias (successful anglers may fish longer than unsuccessful anglers) and frequency-of-use bias (ardent anglers fish more frequently) are common to surveys (Sinclair and Morley 1975), particularly when reported catch rates from incomplete trips are used in the traditional ratio method of catch estimation (Otto 1971). These potential biases are absent from this survey, since anglers were sampled in proportion to their frequency of occurrence and the direct method was used in estimating total catch and effort. Also, the traditional ratio method requires a positive correlation between catch per fisherman and fishing effort and fishing pressure. Since no such correlation was found in the data from the causeway (the upriver sites were not examined), a ratio type estimate of catch would be misleading. It is generally agreed that the direct method is more precise (Carlander et al. 1958; Otto 1971).

Creel survey sampling efficiency depends upon the sampling scheme. Compared with simple random sampling, the Horvitz-Thompson, "A" stratification and "B" optimally stratified sampling schemes were progressively more efficient. The results of these sampling schemes agree generally with those of Otto (1971), in that the most effective stratification factors include location, month, time of week and time of day. Within a given sampling scheme, e.g., the "B" stratification, optimal allocation of sample size provides further gains in efficiency (Abramson and Tolliday 1959; Otto 1971). These investigations also conclude that optimal allocation of sample size from a previous year's data produced the greatest efficiency. Should future creel surveys be conducted of the Annapolis River striped bass fishery, it would be possible to construct a very efficient sampling design based on the present survey, with consequent savings in manpower and costs and improved accuracy of catch and effort estimates.

Comparison of the life history data for Annapolis River striped bass collected by this survey with that collected by Penney (1973) reveals several differences. The mean fork length of the sampled population increased 10 cm in a three-year period. A marked shift to larger fish is observed in the length-frequency data, i.e., no fish smaller than 43.0 cm were caught in 1975, while 14% of the 1973 catch was less than 43.0 cm (Penney, G.H. personal communication). The sex ratios have changed, with proportionately more females appearing in 1975. This shift in sex ratio may be partly attributed to the older age composition of the population and the general tendency towards greater numbers of females in older age groups (Merriman 1941; Williamson 1974). Sex ratios of striped bass in the Annapolis and Saint John rivers (Williamson 1974) are similar, as are the growth patterns (Williamson 1974; Dadswell 1976).

Since contamination of fish and other aquatic organisms by mercury and organochlorides (pesticides and polychlorinated biphenyls or PCBs) is apparently common and widespread (Zitko 1971; Holden 1973), it is not surprising to find that striped bass from the Annapolis River are also contaminated. The mercury levels for the fish tested were less than 0.5 ppm, the established limit for human consumption in Canada and the United States. In comparison, mercury levels of striped bass of comparable weight from Long Island, New York, fluctuated at about 0.5 ppm (Alexander et al. 1973), while fish from the Saint John River (weight not reported but comparable) averaged considerably more than 0.5 ppm (Dadswell 1975, personal communication). Fish larger than those sampled are not uncommon in the Annapolis River and, in view of the relationship between mercury content and weight (Alexander et al. 1973), would undoubtedly contain more than desirable levels of mercury.

In terms of effect on stock survival, organochlorides such as pesticides and polychlorinated biphenyls are of greatest concern, particularly at the levels encountered. Total DDT concentrations in the ovaries of Annapolis River striped bass weighing more than 5 kg were within the range known to cause extensive mortality to winter flounder eggs (Smith and Cole 1973) and to severely affect the development of striped bass eggs (Jagolinzer 1973, cited by Dadswell 1976). Salmonid larval mortality, particularly at the time of yolk sac absorption, is also significant at the DDT concentrations found (Burdick et al. 1964; Macek 1968; Burdick et al. 1972), and striped bass may be similarly affected. Behavioural, motor and sensory impairments are also found in various fishes (Anderson and Prins 1970; Davey et al. 1972; Dill and Saunders 1974), but these effects have not yet been studied in striped bass.

Polychlorinated biphenyls are less toxic to fish than organochloride pesticides, and their toxicological effects are uncertain at levels commonly found (Zitko 1971). Koch et al. (1972) indicate that long-term exposure of larval fathead minnows *(Pimephales promelas)* to PCBs results in inhibition of ATPase activity, which could have undesirable growth and metabolic consequences.

The probable negative effects of DDT and PCB concentrations in striped bass – coupled with the recent changes in population structure, the heavy exploitation of large female striped bass upriver during the spawning season, the finding of very few eggs, and the failure to capture larvae or juveniles – indicate that the indigenous striped bass population of the Annapolis River is in danger of collapse, with consequent severe effects upon the sport fishery. Similar conditions and concern have been reported by Dadswell (1976) for the striped bass of the Saint John River.

A part of the Annapolis River striped bass population is presumed to be migratory and to originate elsewhere. This assumption is unproved but, if true, might continue to provide angling at a reduced level.

APPENDIX A

ANGLING BY BOAT

During the creel survey, 118 anglers fishing from boats were interviewed in 40 4-hour sample periods. The mean number of fishermen per sample was 2.95 (range 0-7). Of the total, 85 anglers had completed trips which will be used in the following analysis.

Interviews with local residents (Annapolis and Kings counties) accounted for 68% of all interviews, while less than 5% of the anglers came from out of province. Anglers reported fishing for 340.25 hours and catching 12 striped bass, for a catch rate of 0.04 fish per hour. On a per-sample basis, reported catch rate ranged from 0 to 1.4 fish per hour.

Examination of fishing effort at upriver (midway and Bridgetown) and causeway (including trailer park) sites revealed several differences. Fishing activity upriver was greatest during May and June, while fishing at the causeway began in July and peaked in August, as shown by the following table.

Month	Number of boat anglers	
	Upriver	Causeway
May	19	1
June	11	0
July	5	8
August	0	40
September	0	1
Total	35	50

Over 97% of anglers sampled while fishing upriver by boat were Nova Scotia residents, of which 63% were Annapolis County residents. Ninety-two percent of anglers launching boats from the causeway were provincial residents, of which only 22% were from Annapolis County.

Estimates of total catch and effort by boating anglers were not made because of the limited data. The sampling design which proved effective for surveying the shore-based striped bass fishery was unsuitable for the boat fishery, because the boats were almost always hidden from view by bends in the river, and because the sampling frequency was insufficient to accommodate the irregular nature of the fishery.

Reported fishing effort at upriver sites totaled 136.33 hours, with a catch of 12 fish, for a catch rate of 0.09 fish per hour. Eleven of the 12 fish were caught in May, one in June. Near the causeway, anglers reported fishing 203.92 hours and catching no fish. The sampling and more extensive general observations indicated that the boat fishery involved a small number of anglers and fish caught, when compared to the shore fishery.

Baits used by boat fishermen were placed in four categories, since the frequent use of several types of bait during a trip made bait preferences difficult to determine. The categories were: plugs, including rapala and cisco kid; lures and other baits, including spoons, squid, earthworms, and rubber eels; plugs and lures combined; and whole alewives.

Of 39 anglers interviewed, 57% used plugs, 30% used lures and other baits, 10% used a combination of plugs and lures, while 3% used whole alewives. Half of all fish caught were taken by cast or trolled plugs.

APPENDIX B

MEAN NUMBER OF ANGLERS AND STRIPED BASS CATCH AT CAUSEWAY AND UPRIVER SITES, ANNAPOLIS RIVER CREEL SURVEY, 1975

Date	Upriver				Causeway			
	No. of samples	Mean no. of anglers	S.D.	Catch per hour	No. of samples	Mean no. of anglers	S.D.	Catch per hour
May 10-17	6	0.0	—	0.0	2	0.0	—	0.0
May 18-24	7	2.6	2.99	0.16	7	3.4	3.51	0.04
May 25-31	10	3.2	4.32	0.07	4	2.8	2.06	0.11
June 1-7	12	2.4	3.32	0.08	3	4.0	1.00	0.07
June 8-14	12	0.8	1.47	0.32	4	6.8	5.25	0.11
June 15-21	11	1.4	1.96	0.26	4	7.5	5.80	0.04
June 22-28	11	0.7	0.91	0.0	4	9.3	10.72	0.0
June 29-July 5	13	0.6	1.19	0.0	4	19.0	7.79	0.03
July 6-12	10	0.4	0.84	0.0	5	12.2	4.49	0.03
July 13-19	8	0.0	—	0.0	6	18.0	7.64	0.07
July 20-26	12	0.0	—	0.0	4	11.5	4.44	0.06
July 27-August 2	11	0.0	—	0.0	6	17.5	6.83	0.06
August 3-9	8	0.0	—	0.0	9	13.4	7.27	0.05
August 10-16	10	0.0	—	0.0	7	13.1	4.81	0.06
August 17-23	8	0.0	—	0.0	7	11.0	5.66	0.0
August 24-30	8	0.0	—	0.0	8	6.6	3.66	0.0
August 31-September 6	10	0.0	—	0.0	8	7.0	7.41	0.0
September 7-13	1	0.0	—	0.0	8	16.5	7.75	0.09

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